

REMARKS

Claims 1-158 are all the claims pending in the application. Claims 1-56 and 158 are elected. Claims 57-157 are withdrawn from consideration by the Examiner.

Reconsideration and review of the claims on the merits are respectfully requested.

Preliminary Matters

Applicants appreciate that the Oath/Declaration and the formal drawings filed on January 14, 2002, are accepted by the Examiner.

Applicants also appreciate the Examiner's consideration and return of an initialed and signed copy of the Information Disclosure Statement filed on March 6, 2002.

Claim Rejections - 35 USC § 103.

A. Claims 1, 3, 5, 7, 9, 11, 21, 22, 25, 26, 29-33, 39-43, 49, 50, 53 and 54 are rejected under 35 U.S.C. 103(a) as assertedly being unpatentable over Marlin (US Patent 6,429,046) in view of Chan et al (US Patent 5,471,092) for the reasons given in the Office Action.

Claims 2, 4, 6, 8, 10, 12, 23, 24, 27, 28, 34-38, 44-48, 51, 52, 55 and 56 are rejected under 35 U.S.C. 103(a) as assertedly being unpatentable over Marlin in view of Chan et al and Darveaux et al (US Pat. 6,201,305) for the reasons given in the Office Action.

Regarding claim 1, the Examiner recognizes that Marlin fails to teach an intermetallic compound being formed between the solder bump and the UBL. However, the Examiner asserts

that Chan et al teaches a solder ball/UBL reflow structure where an intermetallic compound including metals such as tin (Sn) and copper (Cu) is formed after solder reflow of tin based alloy solder having tin as a main component on a metal/solder reactive layer comprising copper to prevent formation of the intermetallics in the underlying layers, improve adhesion and to reduce the joint stress, the intermetallic compound/Cu-Sn including the main component/metal (Sn) of the alloy solder and the second metal such as Cu, which is different than the main component of the alloy solder.

Regarding claim 2, the Examiner asserts that Darveaux et al makes up for the deficiencies in Marlin and Chan by teaching a solder ball mounting structure having underbump layer such as nickel on a laminated pad where an intermetallic compound such as tin-nickel (SnNi) is formed, the intermetallic compound including the metal/first metal such as nickel and the main component of the alloy of the solder ball such as tin.

Applicants respectfully traverse the rejections.

Applicants submit that the combination of Marlin with Chan, and further in view of Darveaux, does not disclose, teach or suggest each and every requirement of Applicants' claims.

According to the present invention, a semiconductor device is characterized in that an alloy layer of at least a main component of a solder and a component different from a UBM layer is provided between the solder and the UBM layer. Since part of the UBM layer may melt, the alloy layer may be made of an alloy of a main component of the solder, a component different from the UBM layer, and a component of the UBM layer.

Accordingly, when soldering, the above alloy layer is first formed between the solder and the UBM layer, and thereby diffusion reactions in the following steps are effectively suppressed.

In Chan et al. (USP 5,471,092), from the solder side, a solder (Pb-rich), a solder reactive metal layer (Cu), a phased layer (CrCu), a barrier layer (Cr), a stress release layer (Cu), and an adhesive layer (Cr) are laminated. When the solder melts, the solder is reacted with the Cu layer or Sn of the solder is reacted with Cu of the CrCu layer. When the solder is reacted with the Cu layer, Sn of the solder reacts with Cu to produce a CuSn-alloy layer. As a result, in the case of the Cu layer being thick, a layer structure of solder, CuSn layer, Cu layer, and CrCu layer is obtained. On the other hand, when Sn of the solder reacts with Cu of the CrCu layer, a layer structure of solder, CuSn alloy, and CrCu layer is obtained. In the case of the Cu layer being thin, the entire Cu layer reacts and is dissolved into the solder. As a result, Cu of the CuSn alloy includes Cu of the CrCu layer because Cr does not react. Since Cr has low wettability, Cr does not react with any of Sn, Cu and Pb. Accordingly, the CrCu layer is not an alloy but a CrCu-mixed layer.

The CrCu layer of Chan et al can avoid diffusion. However, Chan et al does not teach or suggest the feature of the present invention such that the alloy layer of at least a main component of the solder and a component different from the UBM layer is provided between the solder and the UBM layer, and thereby diffusion is prevented.

Marlin (USP 6,429,046) discloses an alternative structure as shown in Fig. 4 or Fig. 5 such that, from the solder side, a solder (Pb-free), a Cu layer, a Ni layer, and a TiW layer are

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laminated. However, Marlin's Fig. 6 shows only an example that one of Cu, Au and Ni is included in the solder on a TiW layer, and it is unclear how the layer 304 of Fig. 5 has been processed.

Marlin does not teach or suggest the feature of the present invention such that the alloy layer of at least a main component (Sn) of the solder and a component different from the UBM layer (Ni) is provided between the solder and the UBM layer, and thereby diffusion reactions due to repeatedly applied heat processes are suppressed.

Marlin is directed to forming a solder on a support stud without wetting by forming the support stud of Cu on a non-wettable layer of TiW. Accordingly, if Cu melts to produce an alloy layer as in the case of the present invention, then the melted Cu would become shaped like a ball on the non-wettable (TiW) layer due to surface tension of the solder and therefore cannot keep its shape for bonding to the solder on the TiW layer.

In Darveaux et al (USP 6,201,305), a solder bump is formed on wiring (Cu or Al) by selecting one of Cu, Au, Ni and the like as a pad. However, Darveaux et al is silent on bonding conditions after melting. Accordingly, as in the case of Marlin, it is considered that diffusion reactions proceed due to repeatedly applied heat processes.

As described above, none of the cited references teaches an alloy layer provided between a solder and a UBM layer, of at least a main component of the solder and a component different from the UBM layer. When soldering, the above alloy layer is first formed between the solder

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and the UBM layer, and thereby diffusion reactions in the following steps are effectively suppressed.

It is considered that diffusion proceeds by substitution of metal atoms and grain boundary motion. As for both Cu and Ni, a similar reaction occurs. However, when an intermetallic compound has been formed for one, the other blocks the intermetallic compound to cut diffusion paths. Therefore, when the CuSn is initially formed at their interface, the Ni diffusion is suppressed.

In other words, according to the present invention, the solder and Cu, or the solder, Cu and Ni, react to produce an alloy layer, and thereby diffusion reactions due to repeatedly applied heat processes can be suppressed.

For the foregoing reasons, Applicants submit that the combination of Marlin with Chan, and further in view of Darveaux, does not disclose, teach or suggest each and every requirement of Applicants' claims. Accordingly, Applicants respectfully request reconsideration and withdrawal of the rejections under 35 U.S.C. § 103(a) in view of Marlin, Chan, and further in view of Darveaux.

B. Claims 13 and 17 are rejected under 35 U.S.C. 103(a) as assertedly being unpatentable over Marlin and Chan et al as applied to claims 1, 5 and 9 above, and further in view of Andricacos et al (US Pat. 6,224,690) for the reasons given in the Office Action.

Claims 15 and 19 are rejected under 35 U.S.C. 103(a) as assertedly being unpatentable over Marlin and Chan as applied to claims 3, 7 and 11 above, and further in view of Andricacos for the reasons given in the Office Action.

Claims 14 and 18 are rejected under 35 U.S.C. 103(a) as assertedly being unpatentable over Marlin, Chan et al and Darveaux et al as applied to claims 2, 6 and 10 above, and further in view of Andricacos et al for the reasons given in the Office Action.

Claims 16 and 20 are rejected under 35 U.S.C. 103(a) as assertedly being unpatentable over Marlin, Chan et al and Darveaux et al as applied to claims 4, 8 and 12 above, and further in view of Andricacos et al for the reasons given in the Office Action.

Applicants traverse the rejections.

Based on the remarks presented above in the obviousness rejections over Marlin in view of Chan, and further in view of Darveaux, Applicants submit that neither Darveaux or Andricacos or their combinations fail to overcome the previously cited deficiencies as reflected in dependent claims 13-20.

Accordingly, Applicants respectfully request reconsideration and withdrawal of the rejections under 35 U.S.C. § 103(a).

Based on the remarks presented above in the obviousness rejections over Marlin in view of Chan, and further in view of Darveaux, Applicants submit that neither Darveaux or Andricacos or their combinations fail to overcome the previously cited deficiencies as reflected in dependent claims 13-20.

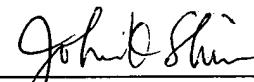
Accordingly, Applicants respectfully request reconsideration and withdrawal of the rejections under 35 U.S.C. § 103(a).

Conclusion

In view of the above, reconsideration and allowance of this application are now believed to be in order, and such actions are hereby solicited. If any points remain in issue which the Examiner feels may be best resolved through a personal or telephone interview, the Examiner is kindly requested to contact the undersigned at the telephone number listed below.

The USPTO is directed and authorized to charge all required fees, except for the Issue Fee and the Publication Fee, to Deposit Account No. 19-4880. Please also credit any overpayments to said Deposit Account.

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